2. "Hydraulics of Closed Conduit Spillways Part X, The Hood Inlet" describes the development of the hood inlet as a simple, economical and easily installed spillway.
3. "Straight Drop Spillway Stilling Basin" used as an erosion control in drainage ditches, as an irrigation drop and check structure and as a spillway for earth dams.
4. "Hydraulic Design of The Box Inlet Drop Spillway" contains sufficient information necessary for the hydraulic design of this type of spillway.
5. "Design Chart For the SAF Stilling Basin". Sheets 1 and 2 give the graphic solution of equations used in the design of the SAF. The basin is proportioned to discharge water into the downstream channel in such a manner as to prevent damaging scour.

Publication by the U. S. Department of The Interior, Bureau of Reclamation. "Design of Small Dams."

This is a new publication (1960) and is a resumé of the more popular design manuals, including those published by the S.C.S. The authors, however, refer the engineer to the original design manual for more complete information.

In addition to these design manuals, Armco Drainage and Metal Products puts out three books that are good references.

1. "Armco Water Control Gates"—a catalogue of gates which includes a wide range of models and sizes for water works and flood control.
2. "Metal Pipe Spillways"—a catalogue of prefabricated metal spillways, specifically the hooded inlet and the riser-conduit spillway.
3. "Handbook of Culvert and Drainage Practice" which includes a catalogue of metal culvert sizes, shapes and coatings.

HYDRAULICS OF DROP INLET SPILLWAYS

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The Soil Conservation Service is concerned with the storage of water in many phases of its work. This storage may be of a temporary nature (a period of approximately 10 days) to alleviate flood damages by manipulating peak runoff hydrographs or it may be permanent storage for wildlife purposes, recreation, or some other use.

Usually, the water is impounded behind an earth fill with a conduit through the fill which has a riser on the upstream side.

After the design hydrograph has been developed, the design of the structure is accomplished by some flood routing procedure which determines the dimensions of the structure and the amount of storage required.

In order to do the flood routing, it is generally necessary to develop a stage-discharge relationship for a spillway which consists of the conduit and riser. A considerable number of variations of this type of spillway have been used, such as CMP with concrete block riser, concrete pipe with concrete riser, etc., with various types of anti-vortex baffle walls.

In the southeastern section of the United States, the flat-top riser as illustrated in Figure 1 is often used in our work under the Small Watershed Act, Public Law 566. Among its advantages are safety and adaptation of a more efficient trash guard. The flat top prevents people from throwing stones and similar material in the riser. It also acts as an anti-vortex device.

In Figure 1 are shown the limiting dimensions of the riser. The cross-sectional area of the riser should be at least one and one-half times the cross-sectional area of the conduit. One of the reasons for this is to eliminate the control of the stage-discharge relationship by the condition known as "short tube flow" which can be difficult to define. Having the depth of the riser equal to or greater than four times the diameter of the conduit insures full pipe flow even though the conduit is put on a slope steeper than normal.

Dimensions such as the distance from the riser weir crest to the underside of the flat-top are in terms of dc which is defined as the critical depth for the discharge over the weir when the conduit first starts to flow full. In Figure 2, this discharge is the one defined by the intersection of the weir-flow and conduit-flow curves.

The riser can be modified in various ways to achieve the desired result. A gate controlled orifice can be installed to discharge from the lower portion of the impoundment providing for a cold water return primarily to reduce damage to downstream fish habitat. Also gates can be installed to provide water-level control to regulate duck habitat.

Figure 3 is a schematic sketch of a conduit and riser which will be used to illustrate the computations for the information in Table 1 necessary to draw the stage-discharge curve in Figure 2.

When water in the impoundment reaches the crest of the riser at elevation 189.0, there is no discharge. As the water rises, weir flow begins. The formula for weir flow is $Q=CLH^{3/2}$. C is a discharge coefficient and has a value of 3.5 in the example; however, 3.1 is recommended. H is the head on the weir in feet and L is the length of the weir in feet. (Note that there is an opening on two sides which makes the weir length 2 x 3D or 12 in this example.) When the water reaches the elevation of 190.2, weir flow fills the riser, submerges the weir, and conduit flow begins. Conduit flow is evaluated by the formula $Q=A \frac{2gh}{1+K_r K_p L}$ where A is the cross-sectional area of the conduit in feet, g is the acceleration due to gravity and equals 32.2 feet per second, h is the head on the pipe and is the vertical distance between the center of outlet of the conduit in the case of a free outlet and the water surface in the impoundment, or in the case of tailwater submerging the outlet, it is the difference in elevation of the two water surfaces in feet. K_r is a coefficient which includes losses in the riser, entrance losses, and bend losses. It varies between 0.4 and 1.2. With a smooth transition from riser to pipe with a well-rounded entrance, the coefficient would approach 0.4. With a sharp-edged pipe entrance and no attempt at a smooth transition, this coefficient would approach 1.2. A value of 1.0 has been used in computations for Table 1. K L is used to evaluate friction loss in the conduit. L is the length of pipe in feet and K_p is a coefficient defined by the formula $K_p=\frac{5087n^2}{d^{4/3}}$, where n is Manning's roughness coefficient and d is the inside diameter of the conduit in inches.

Table 1 is a tabulation of the various heads and discharges for each type of flow for water impounded at various elevations. These data are plotted on Figure 2 to construct the stage-discharge curve. The weir-flow curve is extended above the point where it controls and the pipe-flow curve is extended below the point where it controls. These extensions are shown dashed since they may be termed as theoretical. It is necessary that they be drawn to determine their intersection so that the true curve can be determined. The solid lines therefore make up the stage-discharge curve.

TABLE 1. STAGE-DISCHARGE TABULATION.

	Weir		*Conduit*		
Elev.	*Head*	*Disch.*	*Head*	*Disch.*	*Disch. (Effetive)*
189.0	0	0	20	53.6	0
189.4	0.4	10.6	. .	. . .	10.6
189.8	0.8	30.1	. .	. . .	30.1
190.0	1.0	42.0	21	54.9	42.0
190.2	1.2	55.2	. .	. . .	55.2
190.6	1.6	85.0	. .	. . .	. . .
192.0	. .	. . .	23	57.4	57.4
194.0	. .	. . .	25	59.9	59.9
196.0	. .	. . .	27	62.2	62.2
198.0	. .	. . .	29	64.5	64.5
200.0	. .	. . .	31	66.6	66.6
202.0	. .	. . .	33	68.8	68.8
204.0	. .	. . .	35	70.8	70.8
206.0	. .	. . .	37	72.8	72.8

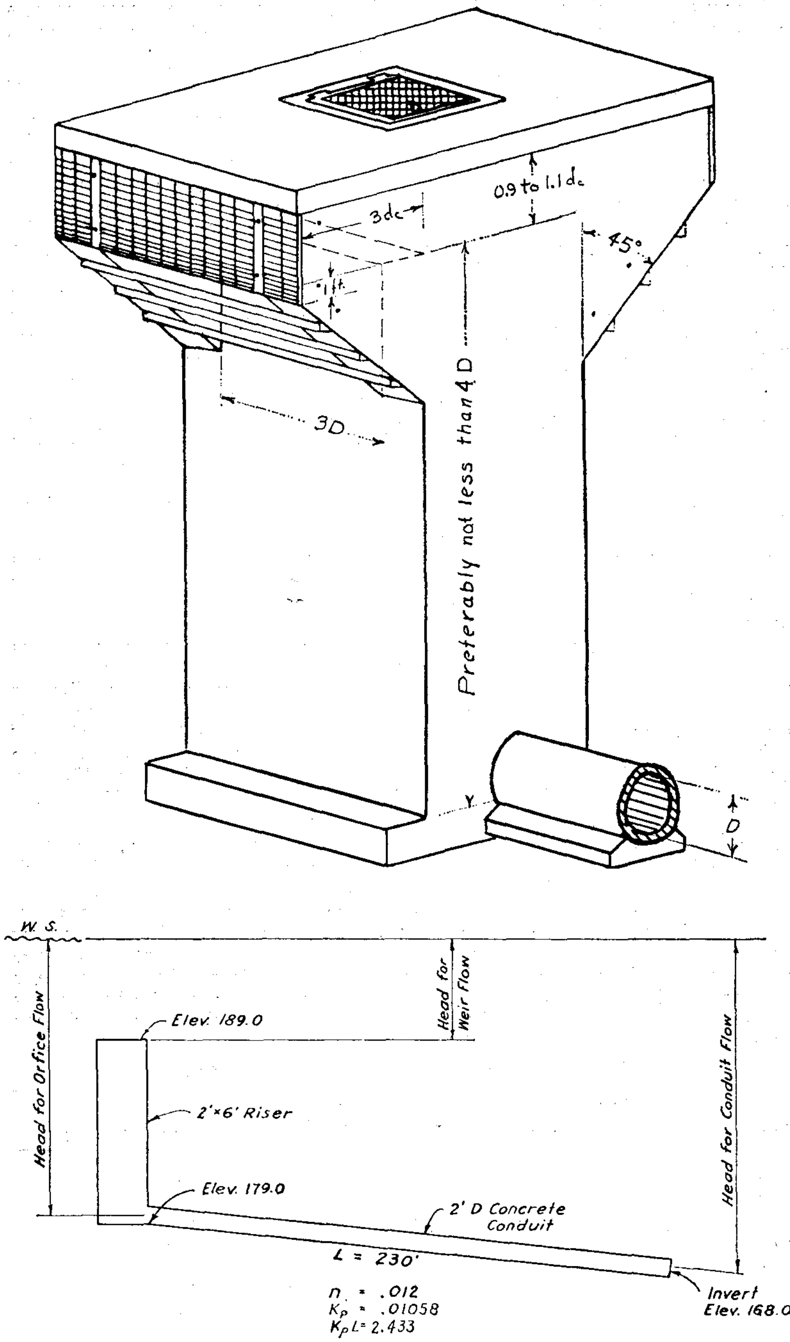
0.9 to 1.1 dc
3dc
45°
1 ft.
3D
Preferably not less than 4D
D
W. S.
Head for Orfice Flow
Head for Weir Flow
Elev. 189.0
2'×6' Riser
Elev. 179.0
2' D Concrete Conduit
L = 230'
Head for Conduit Flow
Invert Elev. 168.0
n = .012
Kp = .01058
KpL = 2.433

Fig. 3

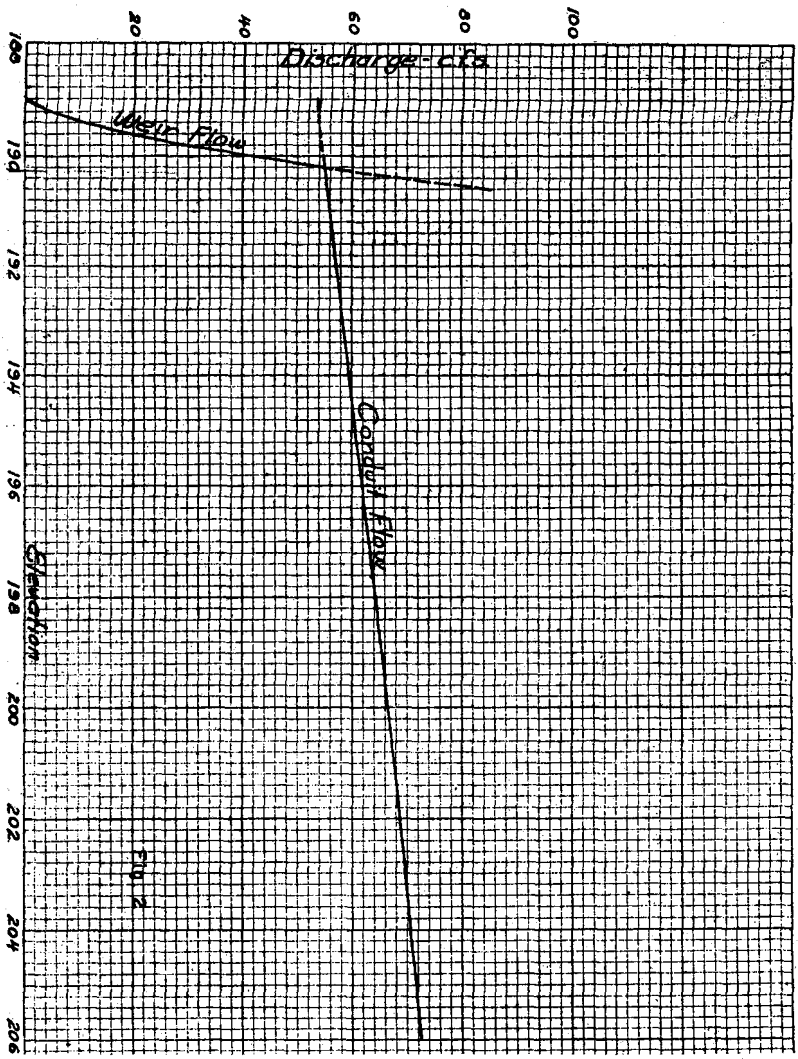
Discharge-cfs
20
40
60
80
100
Weir Flow
Conduit Flow
Elevation
190
192
194
196
198
200
202
204
206

Fig 2